UNIT - 11

CHEMISTRY FOR CLASS IX

SOME USEFUL COMPOUNDS

रा॰शै॰अ॰प्र॰प॰
NCERT

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PREFACE

The present series of twelve chemistry units has been developed for try-out of the Individually Guided System of Instruction (IGSI) in class IX. The description of IGSI and first two units of this series of units are available under a separate cover. This new system of instruction and the units have been developed along the lines of the National Policy on Education (NPE-86) and involve the participation of pupils in the process of learning. The units are suited for self-study with occasional help from a tutor. In the present context, these units will serve as examplar self-study material for secondary stage chemistry. In developing this unit, I was assisted by some of the chemistry teachers.

This unit contains an introduction for motivation, arousing interest, and to link the present unit with preceeding and next units. The objectives given in this unit are the expected learning outcomes, so that the pupil will know the ultimate goals he has to achieve. The suggested reading material provided in the unit guides the pupil to achieve prestated objectives. A number of intext and post-text questions, activities, and problems have been included to provide enough practice and chance for self evaluation.

The suggestions for the improvement of this unit will be welcomed.

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I. Introduction

In previous units, we have studied the uses of various chemical compounds and visualised the usefulness of chemistry in day-today life. For instance in unit-9, we learnt how oxygen is used in producing oxy-acetylene flame which is used for welding purpose In unit-10 we studied that a number of compounds of nitrogen and phosphorus are extensiveiy used as fertilizers to improve the quality and quantity of crops In fact the use of fertilizers has brought green revolution in our country.

In addition to lhe chemical compounds that we have studied, there are a large number of other compounds which find important uses either in industry or in our day-today life. In this unit, we shall study the principles of manufacture of some metallic oxides, hydroxides and salts.

II. Objectives

After completion of this unit, you should be able to

1. Explain the principle of preparation/manufacture of
   (a) *sodium componnds* : sodium carbonate, sodium bicarbonate, sodium hydroxide, and sodium nitrate.
   (b) *calcium compounds* : calcium oxide, calcium hydroxide, bleaching powder, Plaster of paris.
   (c) *copper compounds* : copper sulphate
2. Describe the important properties and uses of compounds mentioned in objective-1
3. Discuss the uses of compounds mentioned in objective-1 and the principles on which the uses are based.

III. Suggested Reading Material

3 1 Sodium compounds

Sodium carbonate Na_2CO_3

In the market, sodium carbonate is sold under a familiar name *washing soda*, its formula being Na_2CO_3, $10H_2O$. Its another familiar form is *soda-ash*, Na_2CO_3. The third commercial form is *crystals of sodium carbonate*, Na_2CO_3 H_2O. The baking soda which is sometimes used in the kitchen for cooking food is sodium bicarbonate, $NaHCO_3$

Manufacture of Sodium carbonate

The manufacturing processes should involve cheap and easily available raw materials. Concentrated brine is the starting material for manufacturing sodium carbonate and sodium bicarbonate Brine is a solution of sodium chloride in water and sea is an endless source of brine.

Solvay Process or Ammonia Soda Process

Sodium carbonate is manufactured by this source. A slow stream of carbon dioxide is passed through a concentrated solution of brine. The gas dissolves in water of the brine solution.

$$CO_2(g) + H_2O(l) \longrightarrow H_2CO_3(aq) \ldots\ (1)$$

Ammonia gas is passed through this solution of brine until the solution is saturated. The following reaction occurs.

$$H_2CO_3\,(l) + NH_3\,(g) \longrightarrow NH_4\,HCO_3\,(aq) \ldots\ (2)$$

Ammonium bicarbonate ($NH_4\ HCO_3$) now reacts with brine giving sodium bicarbonate.

$$NH_4\,HCO_3(aq) + NaCl\,(aq) \longrightarrow NH_4\,Cl\,(aq) + NaHCO_3\,(s) \quad (3)$$

The $NaHCO_3$ separates out from the solution. It is washed with a little water to remove the water soluble impurities. The material is dried, packed and despatched for distribution.

You may now ask—why ammonium bicarbonate (NH_4HCO_3) did not separate out from solution. It is because NH_4HCO_3 is more soluble in water then $NaHCO_3$. Sodium carbonate is obtained by heating sodium bicarbonate.

$$2\,NaHCO_3\,(s) \xrightarrow{Heat} Na_2CO_3\,(s) + H_2O\,(g) + CO_2\,(g) \ldots\ldots (4)$$

Now, let us have a look at the equations (3) and (4).

In equation (3), we have ammonium chloride (NH_4Cl) as one of the product. The carbon dioxide produced during the reaction (4) is used to saturate brine in reaction (1) above. Ammonium chloride (eq 3) is treated with milk of lime $Ca(OH)_2$ to give back ammonia for use in reaction (2). Thus the products carbon dioxide and ammonium chloride obtained as by products during the process are utilized.

$$Ca(OH)_2 + 2NH_4Cl \longrightarrow CaCl_2 + 2NH_3 + 2H_2O \quad \ldots\ldots (5)$$

You will notice that calcium chloride is a by-product in this process

Properties of Sodium Carbonate

Sodium carbonate is a white crystalline solid. It is partially soluble in water.

1. **Alkaline nature** : A solution of sodium carbonate is alkaline to litmus. This is due to the fact that sodium carbonate produces sodium hydroxide in water according to the following equation.

$$Na_2CO_3 + H_2O \longrightarrow 2NaOH + CO_2$$

Action of acid : When sodium carbonate is treated with an acid (HCl), effervescences are given out due to the formation carbon dioxide. You may test carbon dioxide by passing it through lime water.

$$Na_2CO_3(s) + 2HCl\,(l) \longrightarrow 2NaCl\,(aq) + H_2O\,(l) + CO_2\,(g)$$

2. **Efflorescence** : Efflorescence is the process in which a substance loses its water of crystallization. If you keep sodium carbonate $Na_2CO_3.10\,H_2O$ in the open for a long time, efflorescence occurs and it becomes powder. Its molecular formula is $Na_2CO_3.H_2O$.

3. **Action of heat** : On strong heating, sodium carbonate loses water of crytallisation and becomes anhydrous ($Na_2 CO_3$). It melts on further heating at 1125k.

4. **Softening action** : The washerman adds washing soda to water which he uses for washing the cloth. It is because he uses the property of washing soda to (i) remove the hardness of water and (ii) remove dirt due to its alkaline action. The presence of calcium chloride in water makes it hard The water becomes unfit for washing purpose. Sodium carbonate reacts with calcium chloride and calcium carbonate is precipitated out Thus calcium ions are removed from the solution.

$$CaCl_2 (aq) + Na_2 CO_3 (aq) \longrightarrow CaCO_3 (s) + NaCl (aq)$$

Uses

1. Sodium carbonate is used in the manufacture of paper, glass, detergents and sodium hydroxide.
2. It is used in chemical industries as a raw material for making dyes, pigments etc.
3. It is used as a water softening and cleaning agent.

Properties of sodium bicarbonate

Sodium bicarbonate is a white powdery substance with a melting point of 825 K.

1. *Action of heat* : If you heat sodium bicarbonate it breaks up as shown in the following equation.

$$2NaHCO_3 \longrightarrow Na_2CO_3 + H_2O + CO_2$$

2. *Alkaline nature* : Sodium bicarbonate forms sodium hydroxide in water. Thus it acts as an alkali. But it is less alkaline than sodium carbonate.

$$NaHCO_3 + H_2O \longrightarrow NaOH + H_2O + CO_2$$

3. *Action of acid* : Sodium bicarbonate being alkaline in nature, forms salt and water on treating with an acid.

$$NaH\ CO_3 + HCl \longrightarrow NaCl + H_2O + CO_2$$

Uses : Sodium bicarbonate is used

1. in the bakery as baking soda. Sodium bicarbonate is a mild base and releases carbon dioxide on heating. The liberation of carbon dioxide makes the cooking material spongy.
2. as a mild alkali for washing.
3. in the production of sodium carbonate.

Sodium nitrate ($NaNO_3$)

Sodium nitrate used to be a source of nitric acid in the past when it was possible to obtain it from Chile Saltpetre available in Chile from deposits in mines.

Preparation

1. *From chile salt petre* : Chile saltpetre contains sodium nitrate and sodium iodate ($NaIO_3$). The iodate is much less soluble in water. So sodium nitrate can be extracted using water The solution is concentrated and sodium nitrate is obtained by crystallization.
2. *From Soda ash* : Soda ash gives sodium nitrate on treating it with nitric acid.

$$Na_2CO_3(s)+2HNO_3(ag)\longrightarrow 2NaNO_3(aq)+CO_2(g)+H_2O\ (l)$$

Activity

Preparation of sodium nitrate : Take 5-10 grams of soda ash in a beaker and add dilute nitric acid dropwise with constant shaking the mixture The shaking is continued until the effervescence ceases. Add a few drops of blue litmus to check for a slight excess of acid. Acids turn blue litmus red. Now evaporate the solution. Crystals of sodium nitrate separate out on cooling. Decant and dry the crystals.

Properties

Sodium nitrate is a white crystalline solid, soluble in water. It melts at 503K and decomposes above 820K giving sodium nitrite and oxygen.

$$2NaNO_3\ (s) \longrightarrow 2NaNO_2\ (s) + O_2\ (g)$$

The oxygen present in sodium nitrate and its availability at high temperature are indicated when a piece of feebly burning sulphur is brought near molten sodium nitrate. Sulphur burns vigorously and gives sulphur dioxide gas.

$$2S + 2NaNO_3 \longrightarrow Na_2SO_4 + SO_2 + N_2$$

Similarly a feebly burning charcoal starts burning vigrously and produces carbon dioxide gas.

$$4NaNO_3 + 5C \longrightarrow 2Na_2CO_3 + 3CO_2 + 2N_2$$

Uses : Sodium nitrate is used

1. in the manufacture of explosives and fire works. But it is not used in the manufacture of gun powder as it is deliquiscent (absorbs moisture from atmosphere).
2. as a fertilizer.
3. in the production of lead glass.
4. for curing meat.

3.2 Calcium compounds

Calcium occurs in nature as lime stone ($CaCO_3$) or gypsum ($CaSO_4\ 2H_2O$). In the following section, you will study the chemistry of

(i) Calcium oxide, CaO

(ii) Calcium hydroxide, $Ca(OH)_2$

(iii) Bleaching powder, $CaO\ Cl_2$

(iv) Plaster of paris, $(CaSO_4)_2\ H_2O$

3.21 Calcium oxide (CaO)

Its common name is quick lime or caustic lime.

Preparation

Quicklime is prepared in industries on a large scale by heating lime stone ($CaCO_3$) at 1170—1470K in the lime kiln (Fig. 11.1).

The reaction is reversible. Hence carbon dioxide should be removed from the reaction mixture as soon as it is formed.

$$CaCO_3\,(s) \xrightarrow{1170—1470K} CaO\,(s) + CO_2\,(g)$$

The lime kiln is made up of heat resistant bricks. Lime stone is fed into the kiln through a hopper. Heat is provided by burning Coal in fire boxes. There is an opening at the top from where the waste gases and carbon dioxide escape. Quicklime is removed from the bottom outlet.

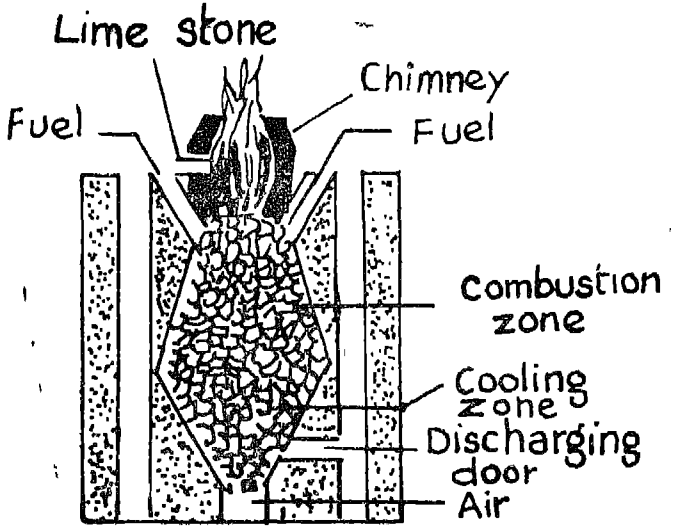

Fig. 11.1 Kiln for manufacture of calcium oxide

Properties : Quicklime is a white porous solid. It melts at 2850K. It is a very stable compound.

Reaction with water : Quicklime reacts with water to give calcium hydroxide. The whole mass crumbles into a fine white bulky powder.

$$CaO + H_2O \longrightarrow Ca(OH)_2 + \text{Heat}$$

This powder is known as slaked lime and the whole process is called *slakening of lime.*

Reaction with acids : Calcium oxide is a basic oxide. It reacts with acids producing the calcium salt and water.

$$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$$

On exposure to air, calcium oxide absorbs moisture and carbon dioxide and forms a mixture containing calcium carbonate and calcium hydroxide.

Uses : Calcium oxide is used

1. in the manufacture of cement, glass, bleaching powder, calcium carbide etc.
2. in paper making
3 in metallurgical processes.

Calcium hydroxide

Quicklime has a great affinity for water. It reacts with water producing a hissing sound and heat. Calcium hydroxide also known as *slaked-lime* is produced as the reaction product. The reaction can be represented as :

$$CaO\ (s) + H_2O\ (l) \longrightarrow Ca\ (OH)_2\ (s) + \text{heat.}$$

Water solubility : Quicklime abosorbs water very easily. After slakening of quick lime, only a very small part of slaked lime dissolves and most of it remains as a white residue. If we allow it to settle and decant the supernatant liquid (layer on top), we get a solution called lime water. It is a clear colourless solution of calcium hydroxide and turns red litmus blue.

Now if we take some slaked lime and shake it with water, it will not dissolve but will remain as a fine white suspension. This suspension is called *milk of lime*. This is calcium hydroxide suspension present in water.

Properties · Calcium hydroxide is a white amorphous powder. It is slightly soluble in water.

Action of heat : On strong heating, calcium hydroxide converts into calcium oxide.

$$Ca\ (OH)_2 \xrightarrow{\text{Heat}} CaO + H_2O$$

Action of carbon dioxide : When carbon dioxide gas is passed through a saturated solution of calcium hydroxide (lime water), milkiness appears due to the formation of calcium carbonate. When excess

of carbon dioxide is passed, the milkiness disappears and the solution becomes clear due to the conversion of insoluble calcium carbonate to soluble calcium bicarbonate, $Ca(HCO_3)_2$.

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

$$CaCO_3 + CO_2 + H_2O \longrightarrow Ca(HCO_3)_2$$

When the solution of calcium bicarbonate is heated, it again acquires milkiness due to the formation of calcium carbonate

$$Ca(HCO_3)_2 \xrightarrow{\text{Heat}} CaCO_3\,(s) + CO_2\,(g) + H_2O\,(l)$$

Action of chlorine : When chlorine gas is passed through a suspension of calcium hydroxide in water (milk of lime), bleaching powder is formed.

$$Ca(OH)_2 + Cl_2 \longrightarrow \underset{\text{Bleaching powder}}{CaOCl_2} + H_2O$$

Uses : Calcium hydroxide is used

1. in the manufacture of bleaching powder, glass, caustic soda, paper and cement.
2. in the purification of coal gas for absorption of acidic gases.
3. in white-washing, a suspension of calcium hydroxide in water is applied on the walls. During drying, calcium hydroxide layer absorbs carbon dioxide from atmosphere and gets converted into calcium carbonate The whiteness in white wash is due to the formation of calcium carbonate.

3.2 Bleaching powder ($CaOCl_2$)

You know that chlorine acts as a disinfectant (a substance capable of destroying disease bacteria) and germicide (substance which destroys germs) You may also recognise its smell. Chlorine, if used as a gas, will escape into the atmosphere and pollute it. If bleaching powder is used instead of chlorine gas by the sides of drains or moss infected areas, chlorine is slowly released due to action of atmospheric carbon dioxide on bleaching powder.

$$CaOCl_2 + CO_2 \longrightarrow CaCO_3\,(s) + Cl_2\,(g)$$

Preparation : Bleaching powder is manufactured by the action of

chlorine on slaked lime. The plant employed (Bechmann's Plant) is shown in figure 11.2.

$$Ca(OH)_2(s) + Cl_2(g) \longrightarrow CaOCl_2(s) + H_2O(l)$$

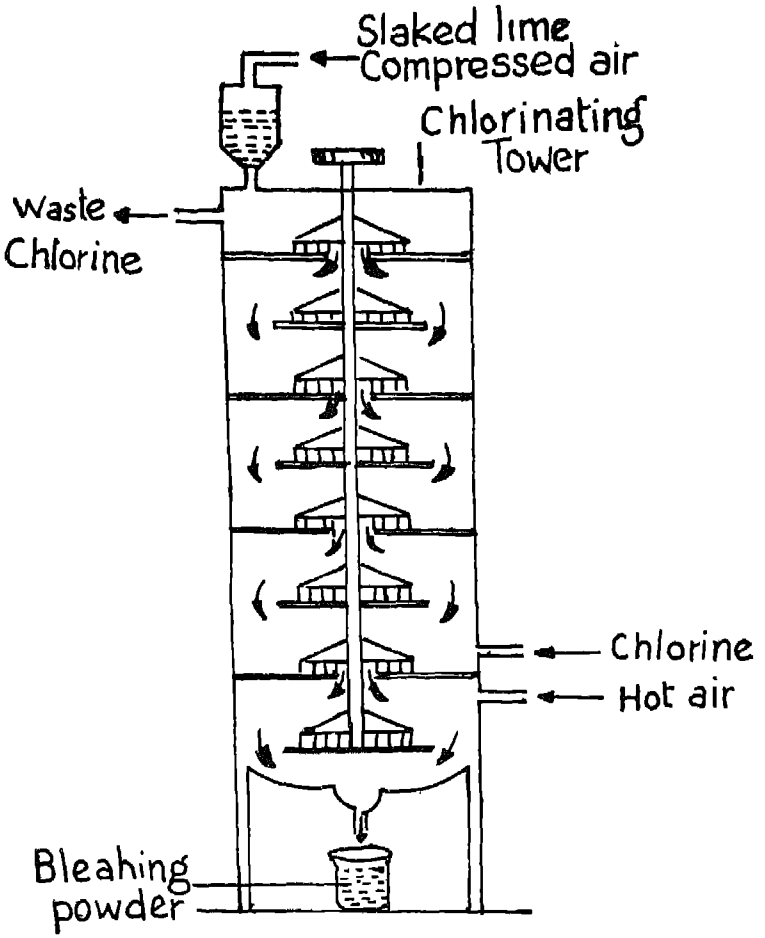

Fig. 11.2 Manufacture of bleaching powder

Properties : Bleaching powder is a white powder and has a strong smell of chlorine.

It reacts with carbon dioxide and produces chlorine gas.

$$CaOCl_2 + CO_2 \longrightarrow CaCO_3 + Cl_2$$

Bleaching powder reacts with dilute acids and releases chlorine gas.

$$CaOCl_2 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + Cl_2$$

The chlorine thus released in the above reaction is known as available chlorine. This available chlorine is responsible for the bleaching action of bleaching powder. The available chlorine in bleaching powder is 35-40%.

Bleaching is a process in which the colour of any material is discharged or faded. The bleaching action of bleaching powder is based on the following principle.

In presence of slight amount of acid, bleaching powder releases nascent oxygen Nascent means just produced It is highly reactive and a powerful oxidising agent. It is utilized as soon as it is produced in solution. This nascent oxygen is responsible for bleaching action of bleaching powder,

$$2CaOCl_2 + H_2SO_4 \longrightarrow CaCl_2 + CaSO_4 + 2HOCl$$

$$HOCl \longrightarrow HCl + [O]$$

Process of bleaching : The article to be bleached is first dipped in a tank containing a solution of bleaching powder. Then it is dipped into a tank containing dilute hydrochloric acid. Chlorine produced reacts with water and releases nascent oxygen which bleaches the article. After bleaching is complete, it is necessary to remove the excess chlorine as the excess of chlorine can harm the material So the article is dipped into a tank containing sodium bisulphite solution that removes chlorine. It is then washed with water and dried

Uses : Bleaching powder is used

1. for bleaching purposes.
2. as a disinfectant and germicide for sterlizing water.
3. for making wool unshrinkable.
4. in the manufacture of chloroform.

Plaster of paris $(CaSO_4)_2.H_2O$

When someone accidentally fractures a limb like the hand or leg, the doctor puts a plaster round it after positioning it. It is done to

keep the limb in a particular position. The material which the doctor uses for plastering is plaster of paris.

Preparation : Gypsum ($CaSO_4.\ 2H_2O$) is a mineral obtained from mines If it is heated around 393K, it loses some of the water molecules and plaster of paris is formed.

$$2\,(CaSO_4.\ 2H_2O) \xrightarrow{\text{Heat}} (CaSO_4)_2.\ H_2O + 3H_2O \qquad \ldots\ldots (i)$$

Properties and uses

1. If Plaster of Paris is mixed with water to form a paste, the reverse reaction shown in equation (i) takes place giving back gypsum. This material sets into a hard mass in about ten minutes. This is known as the *setting of Plaster of Paris.* Setting of Plaster of Paris finds use in plaster caste in hospitals, for making moulds in pottery, as a cement in ornamental castings for making decorative articles, chalk etc.

2. During the preparation of Plaster of Paris, if the temperature exceeds much above 393K, the $Ca(SO_4)_2.\ H_2O$ loses the last water molecules to give anhydrous $CaSO_4$ The product *dead-burnt-plaster.* Plaster of Paris can be used in fire-proofing since it does not catch fire. Thus the heating process involves controlled dehydration.

3.3 COPPER COMPOUNDS

Copper (II) Sulphate → $CuSO_4.\ 5H_2O$

This blue substance, also known as blue-vitrol is an extensively used chemical.

Preparation

1 Copper sulphate is prepared industrially from the copper scrap obtained as copper waste from industries. A stream of air is blown through a mixture containing copper and dilute sulphuric acid.

$$2\ Cu + 2\ H_2SO_4 + O_2 \longrightarrow CuSO_4 + 2H_2O$$

2 Copper is also obtained from copper ore which is copper pyrite. Copper pyrite is subjected to roasting (heating in presence of air) at controlled temperature. The mixture is converted into sulphate by treating with sulphuric acid Cop-

per sulphate is soluble in water Insoluble iron oxide settles down in the reaction mixture.

Properties : Copper sulphate is blue in colour. It is highly soluble in water.

Action of heat : The blue crystalline pentahydrate $CuSO_4.5H_2O$, loses water molecules in stages and finally anhydrous salt is obtained. The anhydrous salt. $CuSO_4$, gets back its blue colour when treated with water. Therefore the dehydration of copper sulphate is a reversible process.

$$\underset{\text{Blue}}{CuSO_4\,5H_2O} \xrightleftharpoons{305K} \underset{\text{Pale blue}}{Cu5O_4.\,3H_2O} \xrightleftharpoons{373K} \underset{\text{bluish white}}{CuSO_4\,H_2O} \xrightleftharpoons{505\text{-}523K} \underset{\text{white}}{CuSO_4}$$

Thus if we want to test the presence of water in any aqueous solution, we can add the white anhydrous copper sulphate to it. If water is present, the powder will turn blue due to the formation of $CuSO_4\,5H_2O$.

Uses

1. Copper sulphate is used as a fungcide and germicide in agriculture.
2. It is used in electroplating, electrotyping, calico-printing and dyeing.
3. It is also used to prepare other salts of copper.

IV Home Assignment

1. What are the three common names in which sodium carbonate is available in the market ? Write their formulae.
2. What is brine ? Where from do you get it in large scale ?
3. Write the steps in the manufacture of sodium carbonate by Solvay process. Explain each step with equations
4. Write a chemical equation for the reaction between sodium carbonate and dilute sulphuric acid.

5 Why do sodium carbonate and sodium bicarbonate act as alkali in solution ?

6. What is the effect of heat on sodium bicarbonate ?

7. What are the main constituents of chile saltpetre ?

8. Write equations to show the reaction between molten sodium nitrate and feebly burning carbon.

9. Write the chemical formulae of limestone and gypsum.

10. How is limestone converted to quicklime in a kiln ?

11. Explain the process of slakening of lime.

12. How do you obtain lime-water from quicklime ?

13. Quicklime is used in furnace linings. Why ?

14. How is bleaching-powder manufactured from slaked lime ? Why is it called bleaching powder ?

15. How is blue vitriol prepared from copper pyrites ?

16. Give two important uses each of Plaster of Paris, quicklime, slaked lime, blue-vitriol and sodium hydroxide.

17. Which of the following substances will be the most suitable to neutralize industrial acids that pollute the surroundings.

Na_2CO_3, NaOH, $NaHCO_3$, CaO

Self Assessment

1. Give a brief account of
   (a) bleaching process
   (b) Principle of manufacture of bleaching powder
   (c) different forms of calcium hydroxide.

2. Write chemical equations for the following reactions :-
   (a) heating calcium carbonate
   (b) action of chlorine on slaked lime
   (c) action of passing excess carbon dioxide through lime water
   (d) action of dilute H_2SO_4 on copper turnings in presence of air

3. Write the chemical formulae for the following ;

(i) gypsum

(ii) blue vitriol

(iii) bleaching powder

(iv) Plaster of paris

(v) soda ash

(vi) milk of lime

(vii) baking powder

(viii) dead burnt plaster.

4. Write a brief account of

(a) Solvay-ammonia process

(b) Manufacture of calcium oxide.

5. Which of the following are oxidising agents :

(i) $NaNO_3$, (ii) $CaOCl_2$, (iii) Na_2CO_3, (iv) $CuSO_4.5H_2O$

Teacher's Guide

This unit must be considered as gateway to manufacturing processes and uses of a number of important chemicals to the young learners. The learners should be able to clearly state the principles involved in the various manufacturing processes. They should be introduced to the requirements of a profitable and useful industry through the consideration of

(a) availability of raw materials in the country.

(b) need for conservation

(c) the dependence of one industry over other indusiries and the necessity of development of ancilliary industries.

The learners may be questioned on simple aspects of the above depending on the extent of their learning.

Teaching aids include flow-charts showing the processes of production of various useful substances. Samples of useful chemicals to be studied may be stored in closed bottles for observation by the students. Where ever possible, some demonstration of the properties may be shown. Some of the suggested demonstration experiments are the following :

(a) Action of litmus on $Na_2 CO_3$ solution.

(b) Preparation of milk-of-lime, slaked lime and lime water.

(c) Turning of lime water milky and

(d) Disappearance of milkiness by passing excess carbon dioxide.

(e) Bleaching action of bleaching powder.